Search for extended emission in 4 years of GBM GRBs

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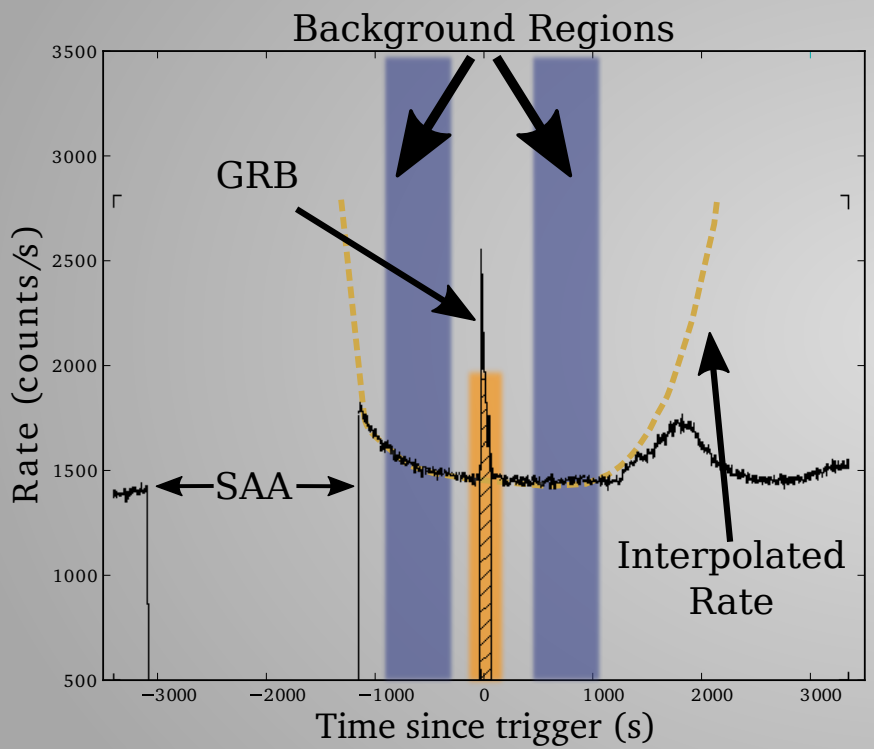
Introduction

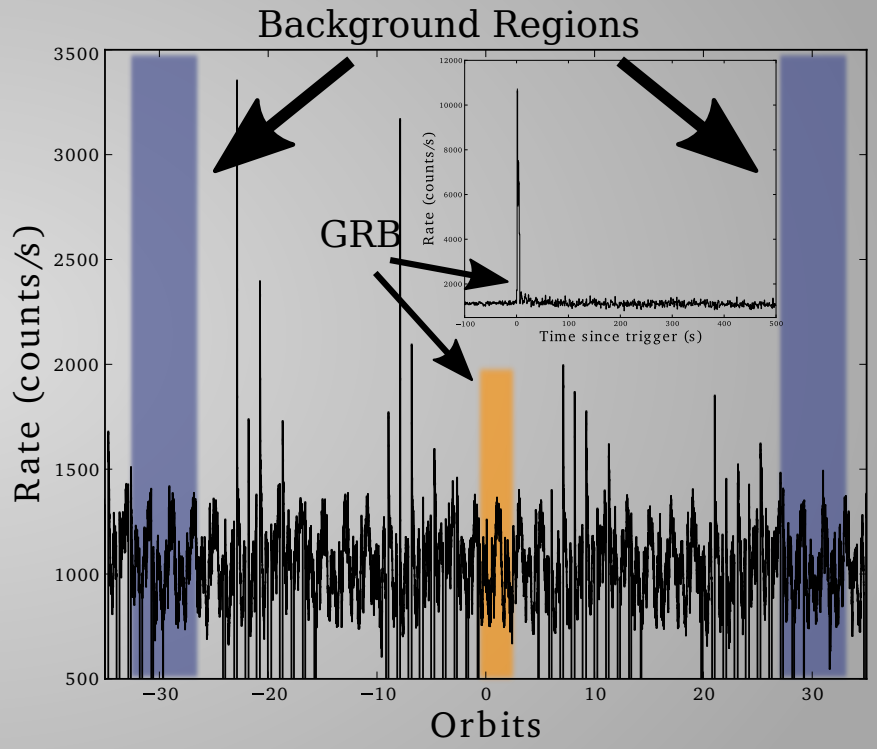
- Extended emission above 100 MeV observed in multiple GRBs with *Fermi* LAT
  - e.g. GRB 090926, observed out to $\sim$5 ks, decayed as a power law of index $\sim$-1.7
- Can be explained as synchrotron emission from the external forward shock [*Kumar & Duran, 2010*, *Ghisellini et al., 2010*]
- BATSE observations [*Connaughton, 2002*]
  - Long GRBs, tails observed out to hundreds of seconds, decayed with a power law of index -0.6 ± 0.1
  - Short GRBs, tail emission much less significant
- Could such emission be observed in GBM?
- Definitions:
  - Prompt emission corresponds to that which occurs during the t_{90}
  - Extended emission is that which occurs after the t_{90}

Background determination in GBM

Polynomial Interpolation

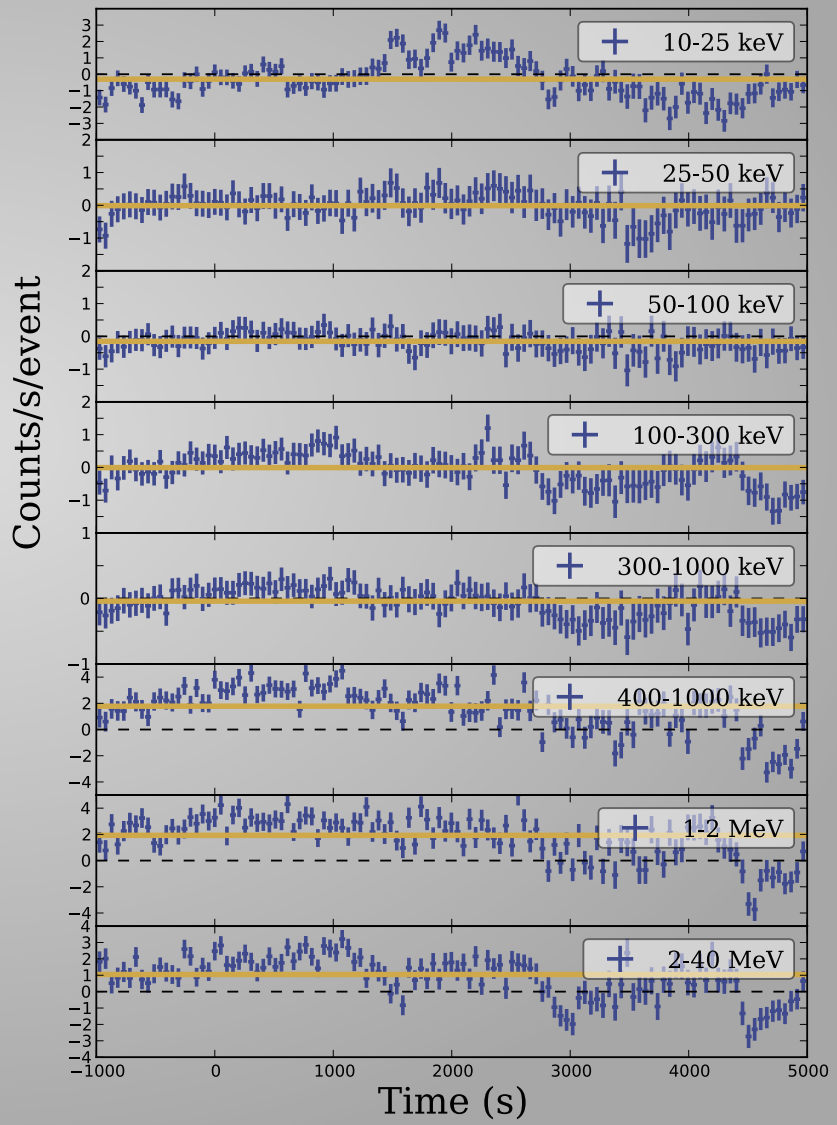


Estimation from offset orbits



Blank Field Tests

- 122 regions without triggers of duration 6 ks selected
- Regions of high solar/SGR activity avoided
- Average Residual lightcurve is consistent with zero emission for NaI bands



Methodology of Search in GBM data

For each GRB:

- generate lightcurve & background (6 ks, 1 ks pre trigger)
- generate good time intervals (GTI) for each detector
  - source not occulted by earth
  - angle to source <60°, 90° for NaI, BGO
- average detector lightcurves

For all GRBs:

- Align by 1 s peak flux time interval (10-1000 keV)
- Average these and generate lightcurves in 8 energy bands as with blank fields
- Used 25-300 keV

GRB Samples

985 GRBs in 4 yrs: 14th Aug 2008[†] - 14th Aug 2012

	All	Bright[‡]
Short	171/	29/
Long	814/	102/

[†] Continuous data not available before this date

[‡] for short, bright = Peak Flux > 4.725 Photons/s/cm^2, for long bright = Fluence > 2e-5 ergs/cm^2

GRB Samples

985 GRBs in 4 yrs: 14th Aug 2008[†] - 14th Aug 2012

	All	Bright[‡]
Short	171/83	29/12
Long	814/249	102/35

Attrition is high!

- SAA exit in any 1 of 3 regions
- Source Occulted soon after trigger
- Interfering sources (e.g. Solar Flares, GRBs, etc ...)
- Mismatched S/C geometry in different regions (e.g. ARR, ToO, etc ...)

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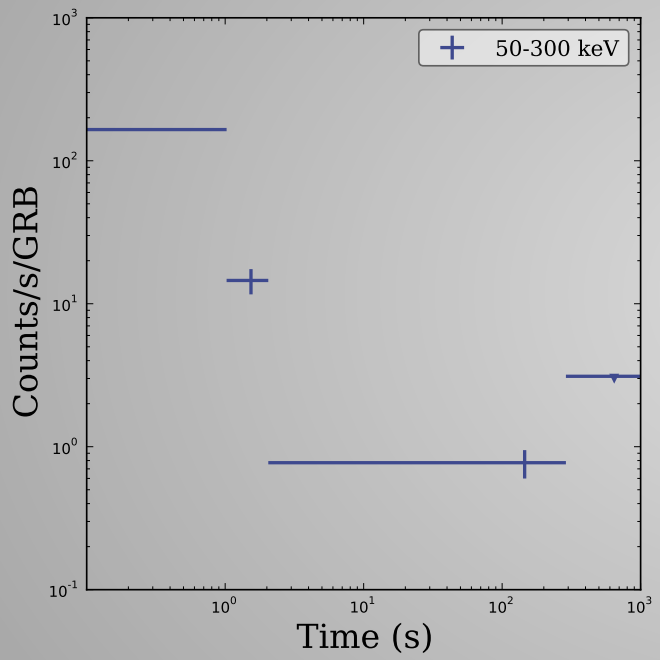
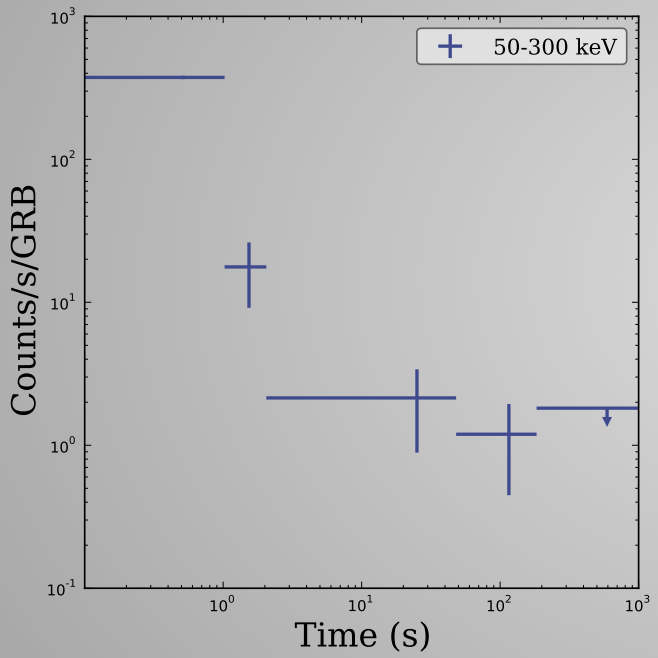
Short GRBs



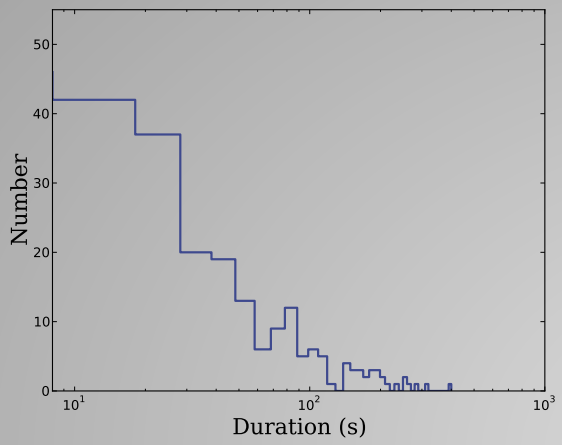
- Low level extended emission observed
- Unable to constrain a power law decay

Short Bright GRBs

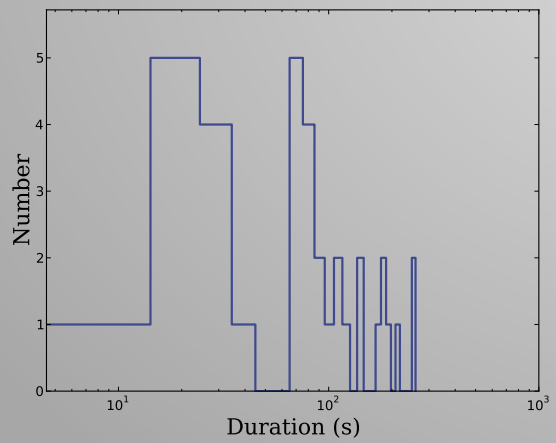


- Low level extended emission observed
- Unable to constrain a power law decay
- Sub samples of candidates with hints of extended emission are being investigated

Long GRBs



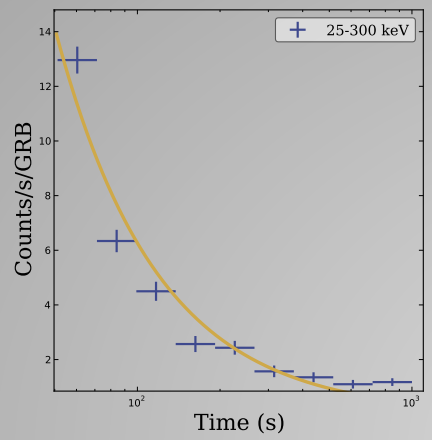
Long GRBs



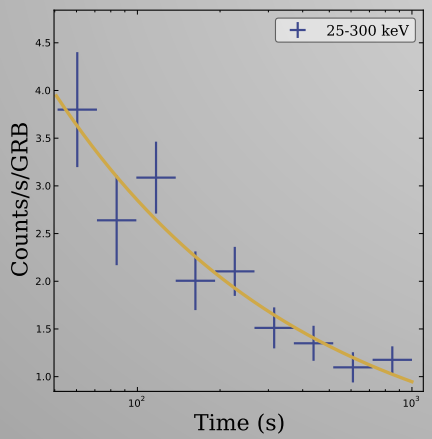
Long Bright GRBs

- Long GRB sample includes many 'long' GRBs
- Supress prompt emission

Long GRBs



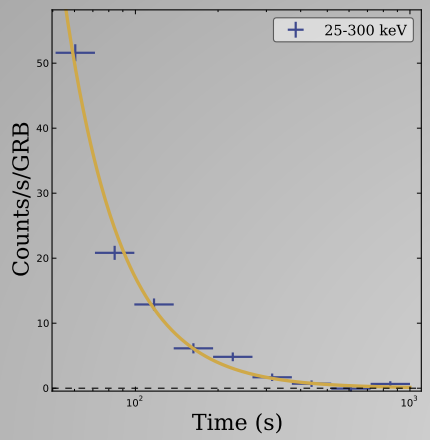
First 50 s removed



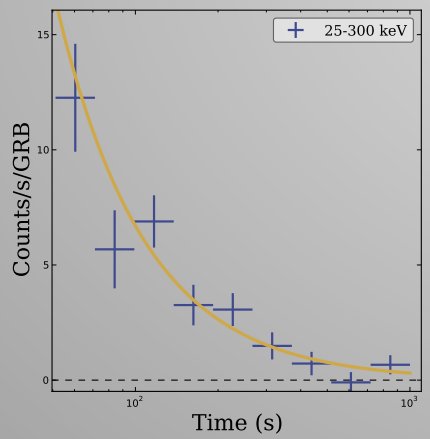
t_{90} supressed

- Including Prompt:
  - 25-300 keV:
    - Decay well described by a power law of index -1.18 ± 0.1
- Supressing Prompt:
  - 25-300 keV:
    - Decay well described by a power law of index -0.5 ± 0.1

Bright Long GRBs



First 50 s removed



t_{90} supressed

- Including Prompt:
  - 25-300 keV:
    - Decay well described by a power law of index -2.11 ± 0.1
- Supressing Prompt:
  - 25-300 keV:
    - Decay well described by a power law of index -1.18 ± 0.1

Extended emission in individual GRBs

- Based on our data, the best case for observing extended emission in an individual GBM GRB is in a bright long event, preferably one with a LAT detection of extended emission
- Have to be careful - ARRs cause mismatch in detector source geometries
- Star List (not comprehensive!)
  - GRB 080916:
  - GRB 090323A:
  - GRB 090328:
  - GRB 090510:
  - GRB 090626:
  - GRB 090902B:
  - GRB 090926:

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- Have to be careful - ARRs cause mismatch in detector source geometries
- Star List (not comprehensive!)
  - GRB 080916: data missing
  - GRB 090323A: bad geometry
  - GRB 090328: bad geometry
  - GRB 090510:
  - GRB 090626:
  - GRB 090902B: bad geometry
  - GRB 090926: SAA

Extended emission in individual GRBs

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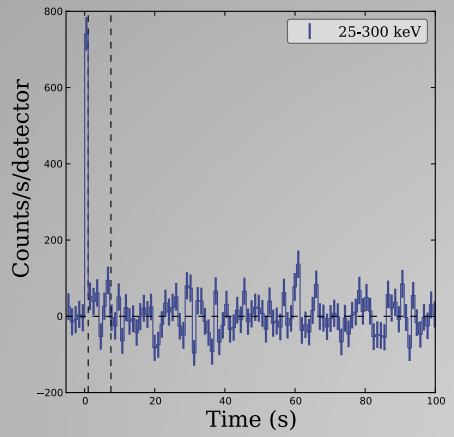
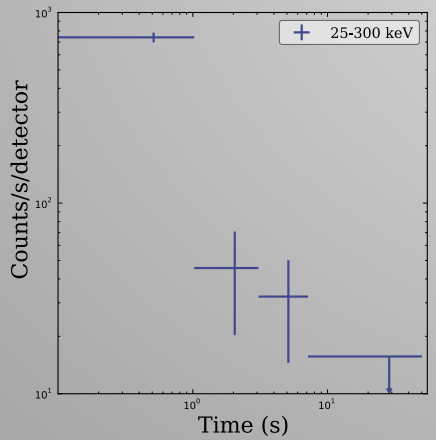
- Have to be careful - ARRs cause mismatch in detector source geometries
- Star List (not comprehensive!)
  - GRB 080916:
  - GRB 090323A:
  - GRB 090328:
  - GRB 090510: good background
  - GRB 090626: good background
  - GRB 090902B:
  - GRB 090926:

GRB 090510



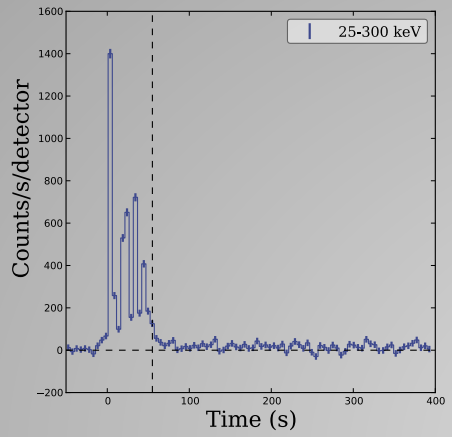
lightcurve



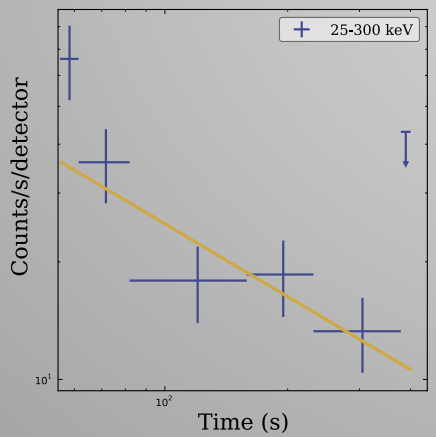
$2\,\sigma$ bins

- Slew starts at $\sim T_0 + 25\,s$
- t_{90} of $\sim 1\,s$
- Possible extended emission for $\sim 7.5\,s$ ($@\sim 2\,\sigma$)
- Possible power law decay

GRB 090626



lightcurve



4.5 σ bins

- Classified by GBM FSW as Local Particles $\rightarrow$ delayed ARR
- t_{90} of $\sim 50 \pm 2.8$ s starting at $T_0 + 1.5$ s
- Ignoring all emission from T_0 to $T_0 + 55$ s we can detect emission until ~ 380 s at 4.5 σ
- Possible power law decay, but index unconstrained: $\sim$-0.6 $\pm$ 0.3

Conclusion

- Trying to find extended emission in GBM is hard!
  - Candidates for extended emission will generally cause an ARR
- Hints of extended emission for short GRBs - more statistics or subsamples?
- Long GRBs
  - Tails are significant to several hundred seconds
  - With prompt: power law decay index of $\sim$-1.18 and $\sim$-2.1 for long and bright long respectively (25-300 keV)
  - Excluding prompt: power law decay index of $\sim$-0.5 and $\sim$-1.3 for long and bright long respectively (25-300 keV)
  - Likely that the contamination from the bright prompt is causing the steepening
- Extended emission observed in two individual GRBs
  - GRB 090510: ~ 10 s (low significance)
  - GRB 090626: ~ 380 s (4.5σ), decays as a power law of index -0.6 ± 0.3